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COMPARISON OF AUTOMOBILE EMISSIONS ACCORDING TO TRIP TYPE IN TWO METROPOLITAN AREAS

by

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ABSTRACT

Estimates of the distribution of automobile emissions among various trip types in the Washington, D.C. area are developed and compared with analogous estimates previously reported for Allegheny County (Pittsburgh), Pennsylvania. Work trips produce approximately equal proportions of emissions in both regions. However, trips to and from the central area and short trips are of considerably lesser importance in Washington than in Allegheny County. In addition, cold starts and evaporations produce a smaller proportion of emissions in the Washington area than in Allegheny County.

These results suggest several ways in which measures that are effective in reducing automobile emissions in Washington are likely to differ from measures that are effective in achieving the same objective in Allegheny County. For example, improved suburban transit service and disincentives to suburban automobile travel are likely to be of greater importance in the Washington area than in Allegheny County. Jitney service or other measures oriented toward short trips may be of greater value in Allegheny County. In both regions, however, cold start and evaporative emissions can significantly impair the effectiveness of transit approaches that rely on the automobile for residential collection and distribution.

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The reduction of automobile emissions of carbon monoxide, hydrocarbons, and nitrogen oxides is a major objective of programs to improve air quality in urban areas. One of the many possible approaches to achieving this objective is to reduce automobile travel. Measures through which this might be accomplished include carpooling, transit improvements, and automobile use fees or restrictions.

Many measures to reduce automobile use can be expected to affect most significantly certain clearly identifiable portions of urban area automobile travel and to have little or no effect on other portions of automobile travel. For example, increased use of freeway bus systems and bus priority treatment are most likely to affect long trips, whereas demand-responsive transit may be best suited to short trips. Park-and-

ride transit service may reduce automobile vehicle miles travelled (VMT) but is unlikely to reduce automobile trip frequencies. Transit improvements generally may be best suited to work trips or trips to and within high density areas, whereas other types of trips may be responsive to certain kinds of automobile fees or restraints. Because measures to reduce automobile use do not affect all types of trips equally, the potential emissions reduction effectiveness of such measures depends on the distribution of automobile emissions among trips of various purposes, lengths, origins, and destinations.

The distribution of emissions among trip types and the potential effectiveness of measures to reduce automobile use and emissions can be expected to vary from city to city, depending on such factors as the lengths and geographical distribution of trips. Estimates of the automobile emissions attributable to various types of trips in Allegheny County (Pittsburgh), Pennsylvania were presented in a previous paper (1). In this paper, the analysis is extended to the Washington, D.C. area. Estimates are presented of diurnal evaporative hydrocarbon emissions, which are independent of travel behavior; cold start and hot soak emissions, which depend on trip volume but not on trip length; and the distributions of emissions according to trip purpose, length, origin and destination, and time of day. The Washington results are compared with those previously obtained for Allegheny County, and implications for the potential emissions reduction effectiveness of measures to reduce automobile use in the two regions are discussed.

Methodology

The Washington emissions estimates were developed for an 870 sq. mi. area surrounding Washington, D.C. (Figure 1). Data from the 1968 Washington transportation survey were obtained giving weekday automobile driver trips between traffic zones in the Washington area for each of five trip purposes (home-based work, shop, school, and social/recreational, and all other) during peak and off-peak periods. Peak period trips were defined as trips terminating in the periods 7:10 - 9:10 AM and 4:40 - 6:40 PM. Roadway distances between each zone pair and zone-to-zone travel times were also obtained. Average zone-to-zone speeds were computed by dividing trip lengths by travel times.

The data were used to develop projections of automobile emissions attributable to Washington area internal trips in 1975 subject to the assumption that travel patterns in 1975 will be the same as in 1968. This approach, which was also used in the Allegheny County study, enables the emissions estimates to reflect the effects of automobile emissions controls while avoiding the need to develop projections of growth. The emissions estimates presented here therefore apply to a hypothetical region whose 1975 travel patterns are the same as the Washington area internal trip patterns of 1968.

Emissions were computed for each trip in the Washington area data set and then summed over trip types to obtain emissions estimates by trip type. Since the age of the vehicle used for a given trip is not included

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in the data, emissions for each trip were averaged over the age distribution of the Washington area automobile population. The emissions estimation model that was used is described in detail elsewhere (1) and is presented in abbreviated form here:

$$(1)\quad E_p = L[s_p(v)e_p + k_p] + \alpha C_p + h_p$$

where

E_p=Emissions of pollutant p attributable to a trip (in kg.)

L=Length of trip (in mi.)

$s_p(v)$=Speed adjustment factor for pollutant p and trip speed v.

e_p=Running exhaust emissions of pollutant p (in kg./mi.) averaged over the vehicle population.

k_p=Crankcase emissions of pollutant p (in kg./mi.) averaged over the vehicle population (non-zero only for hydrocarbons).

α =1 if trip begins with a cold start and zero otherwise.

c_p=Cold start emissions of pollutant p (in kg.) averaged over the vehicle population.

h_p=Hot soak evaporative emissions of pollutant p (in kg.) averaged over the vehicle population (non-zero only for hydrocarbons).

In addition to these trip related emissions, each automobile maintained in the Washington area was assumed to produce diurnal evaporative hydrocarbon emissions regardless of the use it received.

The equation (1) emissions factors for both the Washington area and Allegheny County are displayed in Table 1. Cold start and running

exhaust emissions were estimated from emissions data reported by AESI (2) and by Austin (3) using methods suggested by Martinez et. al. (4). Cold starts were associated with trips that originated at home or at work. Based on results obtained by General Motors (5), 50 percent of the evaporative emissions measured by the Federal Test Procedure (6) was attributed to hot soaks. The other 50 percent was attributed to diurnal evaporations. Average Federal Test Procedure evaporative emissions were obtained from Sigworth (7) as were crankcase emissions. The speed adjustment factors are from Kircher (8).

Results

Table 2 shows Washington area emissions, VMT, and trip volumes according to trip purpose. Diurnal hydrocarbon evaporations, which are not related to travel behavior, are displayed separately from the travel-dependent hydrocarbon emissions. Home-based work trips cause 35 to 40 percent of automobile emissions, depending on pollutant, and generate a larger quantity of emissions than any other trip purpose. Unidentified other trips, whose emissions are nearly as large as those of work trips, and home-based shopping trips follow in importance. Within trip purpose classes, emissions of all pollutants are approximately proportional to VMT.

The effects of cold starts and hot soak evaporations on the emissions attributable to the various trip purposes are shown in Table 3. Cold starts, which are related to trip volumes but not to trip lengths or

speeds, cause 21 percent of carbon monoxide emissions and 13 percent of trip-related hydrocarbon emissions. Hot soaks, which are also independent of trip lengths and speeds, contribute an additional 20 percent of trip-related hydrocarbons. Thus, 33 percent of trip-related hydrocarbon emissions are independent of trip lengths and speeds. The cold start contribution to nitrogen oxides emissions is slightly negative (-2 percent), indicating that trips beginning with cold starts have somewhat lower nitrogen oxides emissions than trips beginning with hot starts. This reflects the high engine temperatures required for nitrogen oxides formation. Cold starts are of greater importance for home-based work trips than for other trips, because home-based work trips are the only trips that have cold starts in both the home-to-destination and destination-to-home directions.

The effects of cold starts and evaporations are further displayed in Table 4, which shows the emissions attributable to the running portion of trips. 79 percent of carbon monoxide emissions and 63 percent of hydrocarbon emissions occur during actual running.

Table 5 shows the grams per mile emissions rates of trips in the Washington area together with emissions rates obtained from Federal Test Procedure emissions factors adjusted for variations in trip speeds (8). The average Washington area carbon monoxide and hydrocarbon emissions rates are respectively 9 and 13 percent higher than the Federal Test Procedure rates. This is caused by differences between Washington area travel characteristics and those assumed in the Federal test. In the

Washington area, 60 percent of trips begin with cold starts; the average trip length is 5.9 miles, and cars travel 19 miles per day on average. In the Federal test, 43 percent of trips begin with cold starts; the trip length is 7.5 miles, and vehicles are assumed to travel 26 miles per day. Moreover, the Federal test weights each model year's contribution to diurnal emissions in proportion to that model year's VMT, whereas the weights used here are proportional to each model year's prevalence in the vehicle population. Agreement between Washington area and Federal test emissions rates is achieved when the Washington rates are adjusted to reflect Federal test travel characteristics.

Nitrogen oxides emissions have no evaporative sources and are relatively insensitive to cold starts. Hence, Washington and Federal test nitrogen oxides emissions rates are approximately equal.

The distribution of Washington area emissions by time of day for work trips and all trips is shown in Table 6. Peak period trips cause 35 to 39 percent of daily automobile emissions, depending on pollutant. Peak period work trips cause 23 to 26 percent of daily automobile emissions and about 65 percent of daily work trip emissions.

The relationship between emissions and trip lengths is illustrated in Figure 2, which shows the cumulative distribution of Washington area emissions according to trip length. 53 percent of carbon monoxide emissions and 50 percent of hydrocarbon emissions are caused by trips whose length is less than 7 miles. However, these trips are responsible for only 39 percent

of the VMT, indicating that carbon monoxide and hydrocarbon emissions per VMT are higher for short trips than for long trips. This is caused by cold starts and evaporations, whose contribution to average emissions per mile increases as trip length decreases, and by the low speeds of short trips compared to long trips in the Washington area (e.g., 4 mi./hr. for a one-mile trip compared to 22 mi./hr. for a 10 mile trip). Nitrogen oxides emissions rates, which are relatively insensitive to cold starts and variations in speeds, do not vary greatly with trip length. Thus, only 37 percent of nitrogen oxides emissions are caused by trips that are less than 7 miles long.

Despite short trips' high carbon monoxide and hydrocarbon emissions per VMT, short trips have lower emissions per trip than long trips. Trips whose length is less than 7 miles, which produce 37 to 53 percent of automobile emissions, account for 69 percent of all trips.

The relationship of emissions to trip origins and destinations was investigated by dividing the Washington area into five districts (Figure 1). District 1 is the city of Washington. Table 7 shows the emissions attributable to trips of all purposes that originate and/or terminate in each district as well as the emissions produced by District 1 internal and peak period trips. Table 8 displays similar information for home-based work trips. District 1 trips for all purposes produce 33 to 37 percent of total automobile emissions. District 1 work trips produce 17 to 20 percent of total emissions, or roughly half of all work trip

emissions. Peak period District 1 trips cause 15 to 17 percent of total emissions. Roughly 75 percent of the emissions attributable to trips originating and/or terminating in District 1 are caused by trips that cross the district boundary. This proportion increases to about 80 percent when only work trips are considered.

Comparison with Allegheny County

Table 9 shows aggregate demographic, geographic, and travel characteristics of the Washington area and Allegheny County. The Washington area has a larger human population, car population, and geographical area than Allegheny County. Accordingly, Washington has more trips and VMT per day. The average trip is longer and faster in Washington than in Allegheny County. Moreover, Washington area cars are somewhat newer than Allegheny County cars and, on average, travel farther per day.

The aggregate characteristics of automobile emissions in Washington and Allegheny County are displayed in Table 10. Total emissions of all pollutants are considerably greater in Washington than in Allegheny County, reflecting the greater amount of travel in the former region. However, emissions per VMT are lower in Washington than in Allegheny County. This is attributable to several factors. Because the Washington car population is newer, it is cleaner. Thus, the Equation (1) emissions parameters are lower for Washington than for Allegheny County (Table 1). The higher average trip speed in the Washington area also reduces average emissions per mile there. In addition, Washington's longer trip length and greater

daily VMT per car reduce the contribution of evaporative and cold start emissions to average emissions per VMT in the region.

The Federal test method of computing emissions underestimates emissions both in Washington and Allegheny County (Table 10). However, the Federal test assumptions of a 7.5 mile average trip length and 26 miles of travel per vehicle per day are more nearly met in Washington than in Allegheny County. Accordingly, the Federal test method approximates Washington area emissions better than Allegheny County emissions.

The distribution of emissions in the two regions according to emissions type and trip type is shown in Table 11. Evaporations are less important relative to other emissions sources in Washington than in Allegheny County, reflecting Washington's greater average trip length and the greater prevalence of evaporative emissions controls in Washington's newer car population. The cold start proportions of emissions are similar in the two regions. Other things being equal, Washington's greater average trip length would tend to reduce the importance of cold starts there compared to Allegheny County. However, the greater prevalence of evaporative emissions controls in Washington tends to increase the proportion of emissions attributable to cold starts and approximately cancels the effects of the increased trip length.

Home-based work, shop, and social/recreational trips produce a slightly greater proportion of emissions, and other trips a slightly smaller proportion, in the Washington area than in Allegheny County.

Short trips are a considerably more important emissions source in Allegheny County than in Washington, reflecting Allegheny County's relatively short average trip length. Trips less than 5 miles long produce roughly half of the carbon monoxide and hydrocarbons and a third of the nitrogen oxides in Allegheny County. In the Washington area, the proportions are approximately one third and one fifth respectively.

Work trips originating and/or terminating in District 1, the principal city, generate similar proportions of total emissions in Allegheny County and the Washington area. In both regions, District 1 work trips produce more emissions than work trips associated with any other district. However, Washington's District 1 is of considerably lesser importance than Allegheny County's when trips of all purposes are considered. District 1 trips for all purposes produce approximately one third of Washington area emissions, whereas they produce roughly half of Allegheny County emissions. This is a consequence of the relative dispersion of non-work trips in the Washington area compared to Allegheny County (Table 12). Whereas District 1 trips dominate both non-work travel and emissions in Allegheny County, all Washington districts are of approximately equal importance for non-work travel and emissions.

Conclusions

The foregoing results suggest several ways in which measures that are effective in reducing automobile use and emissions in the Washington area are likely to differ from measures that are effective in achieving

the same objectives in Allegheny County. One difference concerns the length of trip toward which emissions reduction measures should be oriented. In the Washington area, approximately two thirds of the carbon monoxide and hydrocarbon emissions and three quarters of the nitrogen oxides emissions are caused by trips that are at least 5 miles long. Thus, measures designed to affect relatively long trips, such as freeway bus service and bus priority treatment, may be especially useful in reducing Washington area automobile emissions. In Allegheny County, trips less than five miles in length and trips longer than five miles generate roughly equal quantities of carbon monoxide and hydrocarbons. Measures serving long trips and measures oriented toward short trips, such as jitney and demand-responsive transit service, are both likely to be important in Allegheny County.

A second difference between Washington and Allegheny County concerns the geographical orientation of the trips toward which emissions reduction measures should be directed. Trips to and/or from the central area of Allegheny County produce approximately half of the county's automobile emissions and, depending on the pollutant, cause 50 to 60 percent more emissions than trips associated with any other part of the county. Thus, measures whose principal orientation is central area trips, such as improved radial transit service and restrictions on central area automobile use, might be highly effective in reducing Allegheny County automobile emissions. In Washington, trips to and/or from the central area are

responsible for only about 35 percent of regional automobile emissions and produce only 10 to 30 percent more emissions than trips associated with certain other parts of the region. Therefore, measures directed at non-central travel, such as improved suburban transit service and extension of automobile use disincentives to the suburbs, are likely to be important supplements to central travel measures in the Washington area.

There are also several ways in which the Washington area and Allegheny County are similar. Work trips cause approximately 35 percent of automobile emissions in both the Washington area and Allegheny County. Central area (District 1) work trips produce about 20 percent of automobile emissions in both regions. Thus, measures directed primarily toward work trips, such as improved peak period transit service and increased long-term parking fees, are likely to have similar effects on automobile emissions in the Washington area and Allegheny County.

Cold start and evaporative emissions, which are independent of trip lengths and speeds, can significantly impair the emissions reduction effectiveness of park-and-ride transit in both regions. The impairment is most severe in the case of hydrocarbons. For example, park-and-ride transit in Allegheny County that requires a one-mile home-to-transit automobile trip and serves work trips whose length exceeds 5 miles would achieve 62 percent of the reduction in automobile hydrocarbon emissions that would be achieved by a transit system that had equal ridership but

did not require automobile access. In Washington, where trips are longer and evaporations are somewhat less important than in Allegheny County, the equivalent proportion would be 66 percent.

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TABLE 1 - AVERAGE EMISSIONS FACTORS[1]

Pollutant	Factor	Washington	Allegheny Co.
CO	e	0.0271	0.0332
	c	0.0723	0.0850
NO_x	e	0.0035	0.0037
	c	-0.0008	-0.0009
HC	e	0.0028	0.0033
	k	0.0001	0.0001
	c	0.0053	0.0061
	h	0.0048	0.0067
	d[2]	0.0062	0.0084

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[1] Symbols and units are as in Eq. 1.

[2] Diurnal evaporations in kg./vehicle/day.

TABLE 2 - WASHINGTON AUTOMOBILE EMISSIONS BY TRIP PURPOSE[1]

PURPOSE	TRIPS		VMT		CO		NO_x		HC	
	Vol.	%	Mi.	%	Kg.	%	Kg.	%	Kg.	%
H.B. Work	922	29	7100	38	257	40	25.3	37	29.4	35
H.B. Shop	639	20	2560	14	95	15	9.4	14	12.2	14
H.B. Soc./Rec.	311	10	1890	10	60	9	7.0	10	7.5	9
H.B. School	82	3	498	3	16	3	1.8	3	2.0	2
Other	1250	39	6700	36	215	33	24.7	36	27.4	32
All[2]	3200	100	18700	100	643	100	68.1	100	78.6	93
Diurnal HC									6.2	7
Total HC									84.7	100

---

[1] Trips are in units of thousands per day, VMT in thousands of miles per day, and mass emissions in thousands of kilograms per day. % refers to trip purpose as percent of total.

[2] May not agree with column totals due to rounding.

TABLE 3 - WASHINGTON COLD START AND HOT SOAK EMISSIONS BY TRIP PURPOSE[1]

PURPOSE	CO			NO_x			COLD START HC			HOT SOAK HC		
	Kg.	% Purp.	% Tot.	Kg.	% Purp.	% Tot.	Kg.	% Purp.	% Tot.	Kg.	% Purp.	% Tot.
H.B. Work	67	26	10	-0.74	-3	-1	4.9	17	6	4.4	15	5
H.B. Shop	23	24	4	-0.26	-3	0	1.7	14	2	3.1	25	4
H.B. Soc./Rec.	11	19	2	-0.13	-2	0	0.8	11	1	1.5	20	2
H.B. School	3	18	0	-0.03	-2	0	0.2	11	0	0.4	19	0
Other	34	16	5	-0.34	-2	-1	2.5	9	3	6.0	22	7
All[2]	138	21	21	-1.53	-2	-2	10.1	13	12	15.4	20	18

---

[1] Mass emissions are in thousands of kilograms per day. % Purp. and % Tot. refer to cold start and hot soak emissions as percentage of trip purpose emissions and total emissions respectively.

[2] May not agree with column totals due to rounding.

TABLE 4 - WASHINGTON RUNNING EMISSIONS BY TRIP PURPOSE[1]

PURPOSE	CO		NO_x		HC	
	Kg.	%	Kg.	%	Kg.	%
H.B. Work	190	30	26.0	38	20.1	24
H.B. Shop	72	11	9.7	14	7.5	9
H.B. Soc./Rec.	48	8	7.1	10	5.1	6
H.B. School	13	2	1.8	3	1.4	2
Other	181	28	25.0	37	18.9	22
All[2]	505	79	69.7	102	53.1	63

---

[1] Includes hot-running exhaust and crankcase emissions. Mass emissions are in thousands of kilograms per day. % refers to trip purpose running emissions as percent of total emissions.

[2] May not agree with column totals due to rounding.

TABLE 5 - WASHINGTON EMISSIONS PER MILE BY TRIP PURPOSE[1]

PURPOSE	CO	NO_x	HC	AV. MI.	AV. MPH.
H.B. Work	36	3.6	4.1	7.7	20
H.B. Shop	37	3.7	4.8	4.0	19
H.B. Soc./Rec.	32	3.7	4.0	6.1	21
H.B. School	33	3.6	4.1	6.1	20
Other	32	3.7	4.1	5.4	20
All	34	3.6	4.5[2]	5.9	20
Federal Test	31	3.7	4.0[2]	7.5	20

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[1] Emissions in grams per mile

[2] Includes diurnal evaporations.

TABLE 6 - WASHINGTON EMISSIONS BY TIME OF DAY[1]

TIME	TRIPS		VMT		CO		NO_x		HC	
	Vol.	%	Mi.	%	Kg.	%	Kg.	%	Kg.	%
Peak	1020	32	6900	37	252	39	24.5	36	29.4	35
Off Peak	2180	68	11900	63	391	61	43.7	64	49.1	58
Peak H.B. Work	570	18	4600	24	168	26	16.2	24	19.1	23
Off Peak H.B. Work	350	11	2500	13	88	14	9.1	13	10.3	12

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[1] Trips are in units of thousands per day, VMT in thousands of miles per day, and mass emissions in thousands of kilograms per day. % refers to trip type as percent of total.

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TABLE 7 - GEOGRAPHICAL CHARACTERISTICS OF WASHINGTON EMISSIONS (ALL PURPOSES)[1]

DISTRICT	TRIPS		VMT		CO		NO_x		HC		AV MI.	AV. MPH
	Vol.	%	Mi.	%	Kg.	%	Kg.	%	Kg.	%		
1 internal	400	12	1220	7	64	10	4.1	6	7.7	9	3.1	13
1 peak	391	12	2860	15	108	17	9.9	15	12.4	15	7.3	17
1	1020	32	6630	35	237	37	23.3	34	28.1	33	6.5	18
2	830	26	5570	30	183	28	20.3	30	22.2	26	6.7	20
3	830	26	5420	29	174	27	19.8	29	21.4	25	6.5	21
4	800	25	5350	29	168	26	19.7	29	20.7	24	6.7	21
5	759	24	5780	31	177	27	21.5	32	21.5	26	7.6	21

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[1] Trips are in units of thousands per day, VMT in thousands of miles per day, and mass emissions in thousands of kilograms per day. % refers to district as percentage of total.

TABLE 8 - GEOGRAPHICAL CHARACTERISTICS OF WASHINGTON EMISSIONS (WORK TRIPS)[1]

DISTRICT	TRIPS		VMT		CO		NO_x		HC		AV. MI.	AV. MPH
	Vol.	%	Mi.	%	Kg.	%	Kg.	%	Kg.	%		
1 internal	119	4	470	3	26	4	1.6	2	2.9	4	4.0	13
1 peak	269	8	2170	12	84	13	7.5	11	9.4	12	8.1	18
1	428	13	3380	18	126	20	11.8	17	14.4	18	7.9	18
2	241	8	2120	11	72	11	7.6	11	8.3	11	8.8	20
3	242	8	2110	11	71	11	7.5	11	8.2	10	8.7	21
4	221	7	2000	11	66	10	7.2	11	7.6	10	9.1	21
5	253	8	2280	12	76	12	8.3	12	8.7	11	9.0	21

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[1] Trips are in units of thousands per day, VMT in thousands of miles per day, and mass emissions in thousands of kilograms per day. % refers to district as percentage of total.

TABLE 9 - AGGREGATE CHARACTERISTICS OF WASHINGTON AREA AND ALLEGHENY COUNTY

	Washington	Allegheny Co.
Population	2,520,000	1,610,000
Area (sq. mi.)	870	728
Area of District 1 (sq. mi.)	61	55
Cars	1,010,000	519,000
Average Car Age (yr.)	3.4	4.2
Total Daily Trips	3,200,000	1,720,000
Total Daily VMT	18,700,000	7,280,000
Average Trip Length (mi.)	5.9	4.2
Average Trip Speed (mi./hr.)	20	18
Average Daily VMT Per Car	19	14
Average Daily Trips Per Car	3.2	3.3

TABLE 10 - AGGREGATE EMISSIONS CHARACTERISTICS OF WASHINGTON AREA AND ALLEGHENY COUNTY

Pollutant	Characteristic	Washington	Allegheny Co.
CO	Total (kg./day)	643,000	348,000
	Per Trip (g.)	201	202
	Per VMT (g.)	34	48
	Per VMT (g., Federal Test)	31	42
NO_x	Total (kg./day)	68,100	27,500
	Per Trip (g.)	21	16
	Per VMT (g.)	3.6	3.8
	Per VMT (g., Federal Test)	3.7	3.9
HC	Total (kg./day)	84,700	48,200
	Per Trip (g.)	26	28
	Per VMT (g.)	4.5	6.6
	Per VMT (g., Federal Test)	4.0	5.1

TABLE 11 - COMPARATIVE DISTRIBUTION OF EMISSIONS BY TRIP AND EMISSIONS TYPE[1]

TRIP OR EMISSIONS TYPE	REGION	TRIPS %	VMT %	CO %	NO_x %	HC %
Diurnal Evap.	Wash.					7
	Alleg.					9
Hot Soak	Wash.					18
	Alleg.					24
Cold Start	Wash.	60[2]		21	-2	12
	Alleg.	57[2]		24	-3	12
H.B. Work	Wash.	29	38	40	37	35
	Alleg.	28	39	39	39	33
H.B. Shop	Wash.	20	14	15	14	14
	Alleg.	14	10	11	10	11
H.B. Soc./Rec.	Wash.	10	10	9	10	9
	Alleg.	8	8	7	8	7
Other	Wash.	41	38	36	39	35
	Alleg.	50	43	43	43	40
Trips shorter than 5 mi.	Wash.	54	24	38	22	35
	Alleg.	70	33	53	31	49
District 1 Trips	Wash.	32	35	37	34	33
	Alleg.	41	40	49	50	43
District 1 Work Trips	Wash.	13	18	20	17	17
	Alleg.	14	23	22	22	19

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[1] % refers to trip or emissions type as percentage of total.

[2] Fraction of trips beginning with cold start.

TABLE 12 - GEOGRAPHICAL CHARACTERISTICS OF EMISSIONS (NON-WORK TRIPS)[1]

REGION	DISTRICT	TRIPS	VMT	CO	NO_x	HC
		%	%	%	%	%
Washington	1	19	17	17	17	16
	2	18	19	17	19	16
	3	18	18	16	18	15
	4	18	18	16	18	15
	5	16	19	15	20	16
Allegheny	1	27	27	27	28	24
	2	19	19	17	18	16
	3	21	19	18	19	19
	4	12	14	11	15	10
	5	11	13	10	13	10

---

[1] % refers to travel to and/or from district as percentage of total.

FIGURE 1 - DISTRICT MAP OF THE WASHINGTON AREA

FIGURE 1

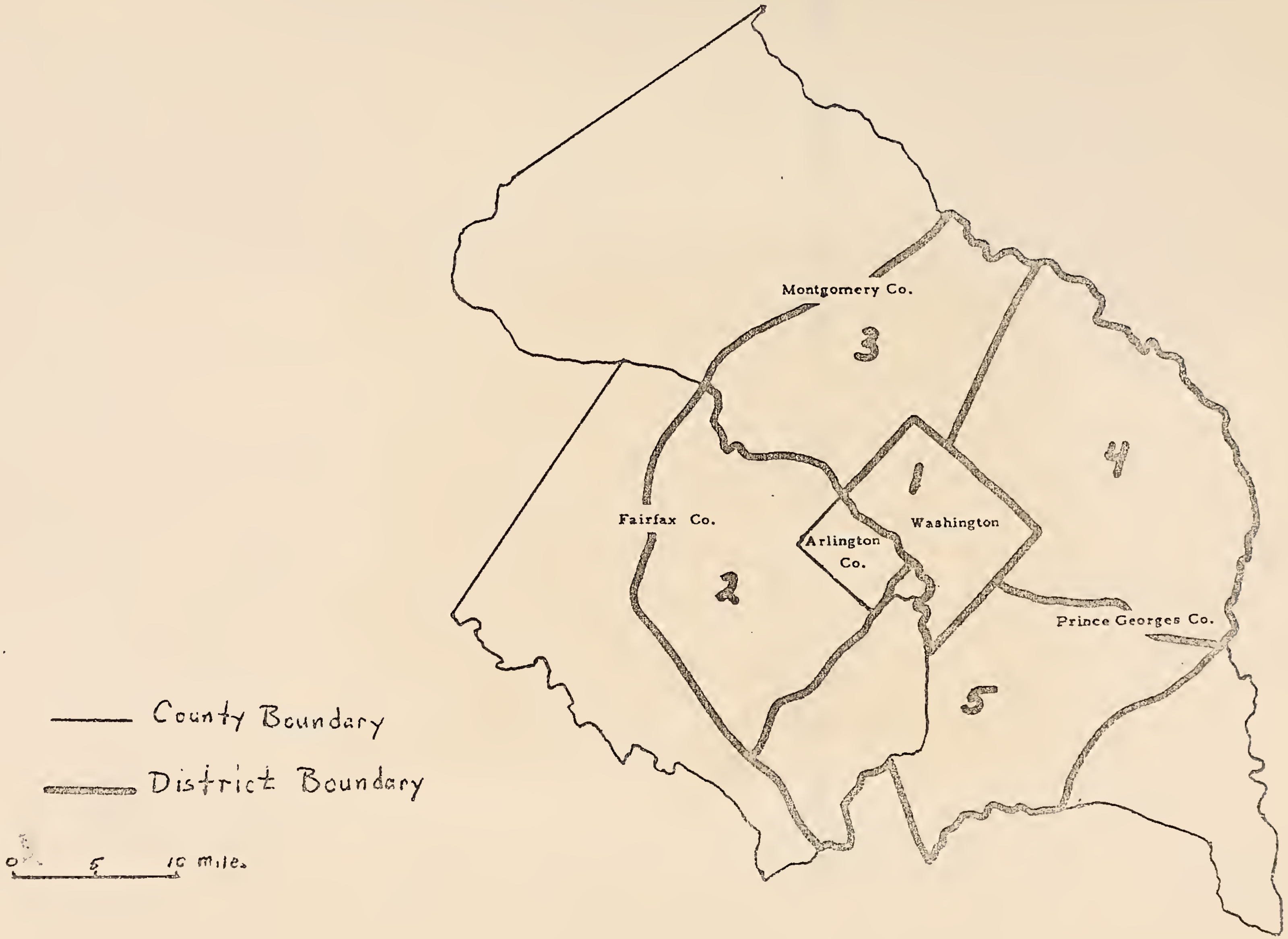
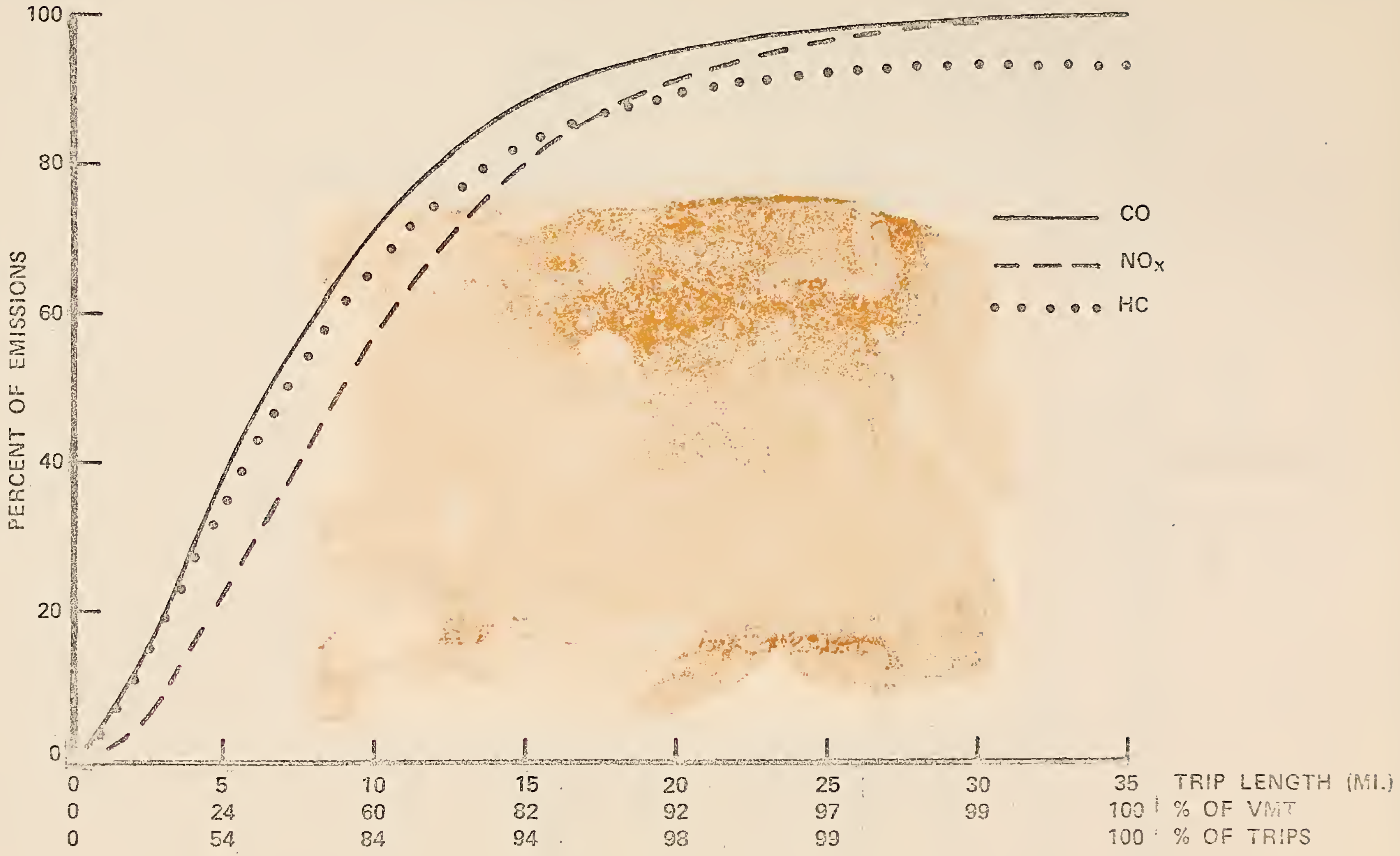

Montgomery Co.
3
4
1
Washington
Fairfax Co.
Arlington Co.
2
Prince Georges Co.
5
County Boundary
District Boundary
0
5
10 miles

FIGURE 2 - CUMULATIVE DISTRIBUTION OF WASHINGTON EMISSIONS BY TRIP LENGTH

FIGURE 2


PERCENT OF EMISSIONS
100
80
60
40
20
0
0 5 10 15 20 25 30 35 TRIP LENGTH (MI.)
0 24 60 82 92 97 99 100 % OF VMT
0 54 84 94 98 99 100 % OF TRIPS
CO
NO$_x$
HC

D16 H
Horowitz, Joel L.
Comparison of automobile
emissions according to
trip type in two metropolitan areas.

D1
Ho
Co
si
tw

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